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学位論文題目	The improvement and hybridization of artificial neural networks and swarm intelligence （人工ニューラルネットワークと群知能の改良とハイブリダイゼーションに関する研究）

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学位論文内容の要旨

学位論文題目: The improvement and hybridization of artificial neural networks and swarm intelligence

（和訳: 人工ニューラルネットワークと群知能の改良とハイブリダイゼーションに関する研究）

専攻　数理・ヒューマンシステム科学

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Computational intelligence (CI) tools are inspired by observable and imitable intelligent activities of nature and human being. These recently proposed tools contain artificial neural networks (ANN), Evolutionary Computing (EC), swarm intelligence (AI), fuzzy systems (FS) and so on. In my research of defending PhD, I focus on the improvement and hybridization of ANN and AI. And my recently research has been illustrated as follows:

Firstly, an approximate logic neuron model (ALNM) based on the interaction of dendrites and the dendritic plasticity mechanism is proposed. The model consists of four layers: a synaptic layer, a dendrite layer, a membrane layer, and a soma body. ALNM has a neuron-pruning function to form its unique dendritic topology for a particular task, through screening out useless synapses and unnecessary dendrites during training. In addition, corresponding to the mature dendritic morphology, the trained ALNM can be substituted for a logic circuit, using the logic NOT, AND and OR operations, which possesses powerful operation capacities and can be simply implemented in hardware. Since the ALNM is a feed-forward model, an error back-propagation algorithm is used to train it. To verify the effectiveness of the proposed model, we apply the model to the Iris, Glass and Cancer datasets. The results of the classification accuracy rate and convergence speed are analyzed, discussed, and compared with a standard back-propagation neural network. Simulation results show that ALNM can be used as an effective pattern classification method. It reduces the size of the dataset features by learning, without losing any essential information. The interaction between features can also be observed in the dendrite morphology. Simultaneously, the logic circuit can be used as a single classifier to deal with big data accurately and efficiently.

Secondly, we proposes a novel plastic neural model (PNM) at the single-neuron level and a specified learning algorithm to train it. The dendritic structure of PNM presents its diversity to fulfill each particular task. During the training process, PNM divides the Euclidean space of the training instances into several appropriate hypercubes which have the same dimensional number. And then each hypercube is transformed into a corresponding dendritic branch in PNM. A suitable dendritic structure of PNM has been proved to have powerful computational capabilities to solve the classification problems. Both theoretical analysis and empirical study of the proposed model

are demonstrated in this paper. Five benchmark problems are employed to verify the effectiveness of PNM in our experiment. And the results of PNM are compared with that of several widely used classifiers statistically.

Thirdly, gravitational search algorithm (GSA) has been proved to yield good performance in solving various optimization problems. However, it is inevitable to suffer from slow exploitation when solving complex problems. In this paper, a thorough empirical analysis of GSA is performed, which elaborates the role of the gravitational parameter G in the optimization process of GSA. The convergence speed and solution quality are found to be highly sensitive to the value of G. A self-adaptive mechanism is proposed to adjust the value of G automatically, aiming to maintain the balance of exploration and exploitation. To further improve the convergence speed of GSA, we also modify the classic chaotic local search and insert it into the optimization process of GSA. Through these two techniques, the main weakness of GSA has been overcome effectively, and the obtained results of 23 benchmark functions confirm the excellent performance of the proposed method.

Fourthly, many optimization algorithms have adopted scale-free networks to improve the search ability. However, most methods have merely changed their population topologies into the scale-free networks. The experimental results cannot verify that these algorithms have superior performances. In this paper, we propose an improved artificial bee colony (SFABC) algorithm with its search guided by a scale-free network. At each iteration of SFABC, honey bees are relocated into the nodes of a scale-free network in the order of their fitness rank, then learn the information of the food source from their neighbors who connect to them in the network. The mechanism enables the search of SFABC follow two rules: firstly, the bad food sources can learn more information from the good sources of their neighbors. Secondly, the information exchange among good food sources is relatively rare. To verify the effectiveness of SFABC, SFABC is compared with the original ABC algorithm, several advanced ABC variants and other heuristic algorithms on a wide rang of benchmark functions. Experimental results and statistical analysis indicate that SFABC gets a better balance between exploration and exploitation during the optimization process, and it can provide competitive performances in most cases of the benchmark functions.

Last but not least, ALNM is a single neural model with a dynamic dendritic structure. During its training process, the model is capable of reducing useless synapses and unnecessary branches of dendrites by neural pruning function. It will provide a simplified dendritic morphology for a particular problem at the end of the training process. Then the final model of ALNM can be substituted by a logic circuit which makes ALNM implemented on hardware easily. However, computational capacity of this model has been greatly restricted by its learning algorithm: back-propagation algorithm (BP). It is sensitive to initial values and easy to be trapped into local minima. To address this critical issue, we have investigated the power of heuristic optimization methods which are acknowledged as global searching algorithms. Through comparison experiments, states of matter search algorithm (SMS) has been verified to possess the superior training performances than BP and other optimization algorithms. When compared with several other popular classification methods, ALNM trained by SMS is also proved to be a more efficient

classifier. Six benchmark datasets are utilized in our experiments, the results and the corresponding statistical tests are presented simultaneously.

The thesis is organized as follows: Chapter 1 gives a brief introduction about artificial neural networks and swarm intelligence. Chapter 2 presents an approximate logic neuron model with a dendritic structure. And Chapter 3 intends to illustrate a novel plastic neural model with dendritic computation for classification problems. Then, in Chapter 4, a self-adaptive gravitational search algorithm with a modified chaotic local Search is proposed. Chapter 5 introduces an artificial bee colony algorithm whose search is guided by scale free networks. Chapter 6 shows the experimental results of approximate logic neuron model trained by states of matter search algorithm. Finally, Chapter 7 gives some general conclusions of this thesis and also points some valuable research trends.

【学位論文審査の結果の要旨】

当博士学位論文審査委員会は，標記の博士学位申請論文を詳細に査読し，また論文公聴会を平成 30 年 08 月 30 日(木曜日)に公開で開催し，詳細な質疑を行って論文の審査を行った。以下に審査結果の要旨を記す。

計算機インテリジェンス（CI）ツールは、自然と人間の知的で観察可能な、模倣可能な活動である。最近提案されたツールは、人工ニューラルネットワーク（ANN)、進化的コンピューティング（EC)、群知能（AI)、ファジィシステム（FS）などを含む。本研究では、このうち ANN と AI の改良とハイブリダイゼーションに焦点を当てている。その概要は、以下の通りである。

第 1 に、樹状突起と樹状突起の相互作用に基づく近似論理ニューロンモデル（ALNM）が提案された。このモデルは、シナプス層、樹状突起層、膜層、および体細胞の 4 つの層からなる。学習中に不要なシナプスや不要な樹状突起を剪定することにより、ALNM は特定のタスクのための独自の樹状突起トポロジを形成するニューロンプルーニング機能を備えている。学習された ALNM は、論理 NOT、AND および OR 操作を用いて、論理回路の代わりに使用することができる。また、ALNM は強力な動作能力を有し、ハードウェアで簡単に実施することができる。ALNM はフィードフォワードモデルであるため、誤差逆伝播アルゴリズムを使用して学習可能である。提案モデルの有効性を検証するために、アヤメ、ガラス、および癌の分類問題が扱われた。シミュレーション実験の結果、パターン分類方法として、ALNM が以下の有効性を持つことが示された。

1）必須の情報を失うことなく、学習によってデータセットの機能のサイズを縮小可能である。

2）特徴間の相互作用は、樹状突起の形態学においても観察することができる。

3）同時に、論理回路を単一の分類器として使用して、ビッグデータを正確かつ効率的に処理することができる。

第 2 に、重力探索アルゴリズム（GSA）の改良法が提案され、最適化プロセスにおける重力パラメータ G の役割が分析された。GSA は、様々な最適化問題を解決する上で良好な性能をもたらすことが証明されている。しかし、問題が複雑になると、最適解への収束が遅れてしまうことは避けられない。本論文では、GSA を改良するため、最適化プロセスにおける重力パラメータ G の役割が解析された。その結果、収束速度と解の品質は G の値に非常に敏感であることを見出した上、探査及び開発のバランスを維持するために、自己適応機構は自動的に G の値を調整することが提案された。さらに、GSA の収束速度を一層向上させるために、古典的なカオス的局所探索を修正し、それを GSA の最適化プロセスに挿入した。これらの 2 つの手法により、GSA の主な弱点が効果的に克服された。

当博士論文審査委員会は、研究内容及び研究成果を慎重に吟味した結果、本博士学位申請論文が博士の学位を授与することに十分に値するものと認め，合格と判断した。